# CHAPTER 6. HABITAT MANAGEMENT PRACTICES.

## 6-1. General

*6-1.1. Definition and Scope.* Habitat, the place where a plant or animal species lives and grows, may include buildings and other man-made structures. The emphasis here, however, is upon more natural areas where vegetation, soil, and water are important features, but where man's influence is usually felt.

*6-1.2. Nature and Purpose.* A primary objective of wildlife management is to manipulate vegetation and other components of the habitat to meet the food, cover, water, and space requirements of desired species and to eliminate the habitat for undesired species. Fish and wildlife populations are affected by man's alteration of the environment, whether done deliberately to increase or decrease populations or accidentally, in connection with agriculture, timber-cutting, urbanization, industrialization, etc. Habitat management for specific wildlife species may effect other species and other natural resources. Management of forest land for maximum production of lumber or other wood products is not necessarily the best management for wildlife; neither are agricultural practices designed to produce the highest yields of agricultural crops per acre. Yet, forest land can be managed to produce both timber and wildlife, promote water conservation, and provide recreation benefits; and agricultural land can be managed to produce both crops of grain and wildlife. Where to place the emphasis and what management techniques to use depend upon the goals and objectives of natural resources management and upon current and potential habitat conditions. Management techniques should be determined by utilizing the multiple use concept.

*6-1.3. Principles.* After surveys have been made of existing wildlife populations and their habitat, and the potentials for habitat development have been determined, goals and objectives for management should be established, including whether the preferred species system (successfully used by the U.S. Forest Service in the Southeast) is to be used, and whether management should be directed towards attaining the maximum multiple-use carrying capacity of the installation. If certain preferred or featured species are selected for special attention, the usefulness or potential of the range available for each species should be estimated. This requires knowledge of the requirements of the selected species. Attention should be given to modifying or removing critical limiting factors; for example, suitable wintering areas might be such a factor for deer in the Northeast. Decisions on management approaches should involve consideration of the effects of management on other species and natural resources and should be biologically and economically feasible.

*6-1.3.1. Cover Diversity and Interspersion.* To increase diversity in wildlife populations, management should be designed to promote diversity or interspersion of food, cover, and water or wetlands of suitable quality and quantity. This involves creating edges where two types of cover join; the "edge effect" is beneficial to many kinds of wildlife (fig. 6-1).

*Figure 6-1. Lespedeza bicolor edge planting for wildlife.*

***6-1.3.2. Requirements of Wild Animals.*** Meeting these requirements is basic to habitat management. Insofar as possible, natural or close to natural conditions should be maintained, and native flora and fauna should be perpetuated.

***6-1.3.3. Featured Species or Unit Management.*** Habitat management on small units may emphasize practices known to be of particular value to certain selected or featured species. Thus: living, mature pine trees with heart rot may be preserved along roadsides or in forested areas within the range of the red-cockaded woodpecker to retain populations of this endangered species; within the range of the American woodcock, alder thickets may be encouraged in moist soil areas in the East; controlled burning may be done in Michigan pine forests to maintain conditions needed for the breeding of the rare Kirtland warbler; and brushy cover intermixed with clumps of evergreens may be maintained for the benefit of ruffed grouse. Management that stresses habitat diversity, even though directed at certain species, usually benefits other species as well.

***6-1.3.4. Periodic Evaluation*** Periodic evaluation of management projects should be made to determine accomplishment of objectives. This involves, primarily, the evaluation of wildlife population and habitat inventory information in relation to stated management objectives.

***6-1.4. Tools and Approaches.*** Among the many management tools and approaches are: creation of new impoundments or wetlands, natural vegetation control, land use regulation, water level control, food and cover planting, erection of nesting tures, waste disposal, and nutrient supplements. Generally, these are mentioned in connection with habitat management on various types of areas, rather than in connection with particular species of fish and wildlife. In habitat management, it is necessary to work within the environmental constraints for each ecological area or physiographic region. A management technique suitable for one installation may not be equally applicable for another in a different region.

**6-2. Wetland Habitat.**

*6-2.1. Definition and Scope.* Wetlands are areas with high soil moisture, in which the ground surface is covered with water at least part of the year. Examples of wetlands are marshes, bogs, and potholes. Streams and lakes, although often associated with wetlands, and man-made fish ponds and larger reservoirs are treated separately. Beaver ponds are discussed in paragraph 6-5.

*6-2.2. Animals Which May Benefit.* Many wetlands, including those in estuarine zones, are highly productive biologically. Coastal salt marshes are extremely important in the lives of many fish valuable for commercial and sport fishing. They also provide habitat for muskrats and other mammals; for many species of birds including waterfowl, herons, and shorebirds; and for numerous other wildlife species. Freshwater marshes and potholes, along with surrounding uplands, constitute the primary waterfowl breeding areas of the country and are utilized by a great number of other species of fish and wildlife. The nation's wetlands have been reduced markedly from their former extent and quality by draining, filling, pollution, and other causes. Wetlands on installations warrant careful maintenance and management. Any actions which affect wetlands must comply with Executive Order 11999, "Protection of Wetland".

*6-2.3. Objectives.* Management objectives should include: (1) optimizing the abundance and diversity of fish and wildlife in the area; (2) assuring the continued availability of habitat capable of supporting fish and wildlife populations at desired levels; (3) helping to assure the survival of the area's natural plant and animal species; and (4) optimizing the kinds, amount, and quality of wildlife and wet-lands-oriented recreation possible in the area.

*6-2.4. Maintenance of Existing Habitat.* If a wetland area is in good condition, every effort should be made to maintain it. This may mean no management, at least temporarily, except to avoid filling it, draining it, grazing it extensively, altering the water level by diversion or consumptive water uses, or permitting pollution. Fencing and posting against trespass may help keep the area intact and reduce disturbance. After a period of years, however, natural plant succession and eutrophication tend to fill in a marsh or change its character, so some rehabilitation measures may be required to keep it productive.

*6-2.5. Rehabilitation and Development.* Among the possible measures for opening up densely vegetated marshes, especially those choked by emergent-type plants, and thus improving conditions for waterfowl utilization, are pothole blasting, level ditching, biological control, chemical control, and drainage ditch plugging.

*6-2.5.1. Potholes.* Blasting to create potholes or open water in marshes is accomplished by using a mixture of ammonium nitrate mixed with fuel oil. Blasting should be done only by qualified personnel or by a licensed and bonded contractor employing strict safety measures. The holes may be five feet or so in depth and perhaps 1,500 square feet in surface area. Small blastouts or potholes are useful in wetlands too thick with vegetation or too dry in summer to maintain waterfowl since they may serve as loafing or feeding sites even though they may not contribute much to waterfowl production (fig. 6-2). Blasting may be warranted in small areas where other means for creating water-holding openings are not feasible. Pothole blasting is further described in Practical Wildlife Management (app B, No. 15).

*Figure 6-2. Shallow-water facility for wildlife, created by blasting.*

*6-2.5.2*. ***Ditches.*** Ditching with a dragline or bulldozer may be cheaper than blasting for larger projects and has the added advantage of leaving exposed soil banks useful for ducks, minks, and muskrats. Ditches four to five feet deep with surface areas of 2,000 to 10,000 square feet and spaced so that there is one opening for approximately each two to four acres of marsh are recommended in Practical Wildlife Management (app B, No. 15).

***6-2.5.3. Biological Control*** The introduction of muskrats can help create open water areas in densely vegetated marshes. However, unless their populations are controlled, muskrats may cause damage to dikes or create vegetative eat-outs greater than desired. Furthermore, in suitable marshes, muskrats are probably already present in numbers attuned to the available habitat. In the north-central United States, a marsh full of cattails, bulrushes, and duck potatoes and with the right amount of water may support thousands of muskrats per square mile, as described in Of Predation and Life (app B, No. 33).

6-2.5.4. ***Chemical Control*** From the standpoint of waterfowl management, dense stands of cattail and other emergent plants are not desirable. The broad-leaved cattail is, however, a prime food of muskrats. Treatment of alternate strips of a marsh with herbicides will create some openings. Thus, it may be possible to manage a marsh both for waterfowl and muskrats. Use of any herbicides should be in accordance with applicable state and Federal regulations.

6-2.5.5. ***Plugging.*** If coordinated with the mission of the installation and not contrary to water district or other regulations, the plugging of drainage ditches and tile lines can restore marshes to productive status. In the experience of the Fish and Wildlife Service, this is best accomplished when site renovations are underway, and a bulldozer is available. Ditch plugs can be compacted in layers by the bulldozer, and tile plugs can be made by excavating a 15-foot section of tile, cementing the ends, and compacting dirt in the excavation.

*6-2.5.6. Burning.* Controlled or prescribed burning may be used to combat or promote specific types of marsh vegetation. Burning has been done in Louisiana to promote Olney bulrush, an important muskrat food in that area, as described in The Muskrat in the Louisiana Coastal Marshes (app B, No. 80). Burning in marsh areas usually is done before birds start to nest in the spring. Additional information on fire ecology may be obtained from publications of the Tall Timbers Research Station (app C, No. 12).

*6-2.5.7. Impoundments.* Some marshes can be improved for wildlife production by the creation of impoundments (i.e., the development of more open water areas). Artificial impoundments can be constructed in wetlands or other lowland areas, both inland and coastal, through the use of bulldozers and draglines and the construction of dams or dikes. Dugouts or dams across small coulees, as in the northern Great Plains area, receive much use by waterfowl pairs and broods and may be beneficial also to mourning doves and other wildlife. When new wetlands and larger impoundments are created, the capability of controlling water levels is very important from a management standpoint (fig. 6-3). Control of water levels facilitates vegetation management since drawdowns can encourage plant growth or permit the seeding of food plants attractive to birds in the fall and winter. Partial drawdowns can encourage growth of plants suitable for brood and nesting cover for waterfowl. If cover is too abundant in relation to open water, raising water levels can kill cattails and other emergent plants.

*Figure 6-3. A flashboard riser for controlling water levels.*

***6-2.5.8 Flooding.*** Flooding a marsh, either through natural causes or deliberately, so that water depths exceed three or four feet, may kill cattails and other plants beneficial to muskrats. Once the cattail growths are gone, one means of restoring them is through partial or complete exposure of the marsh bottom in late summer. Drawdowns which expose bottom soil to sunlight and air can, especially when combined with disking, result in more rapid decomposition of organic materials in the bottom of reservoirs and aid in the rejuvenation of reservoirs which tend to lose fertility or decline in productivity after a few years. Reflooding of the exposed bottom areas, after food plants have become established, facilitates feeding for both waterfowl and muskrats.

***6-2.5.9. Islands.*** When there is too much open water in a marsh, in addition to water level manipluation and control, construction of floating nests sites, rafts, or artificial islands may help. Islands can be constructed most conveniently in connection with new pond or wetland development by leaving higher sections exposed or by dredging and dumping material so it rests above the water level. Islands increase edges and provide for diversification. They are used by waterfowl for loafing and nesting sites and by other animals. Practical Wildlife Management (app B, No. 15) recommends small, circular islands of 10 feet or more in diameter, for ground-nesting ducks.

***6-2.5.10. Greentree Reservoirs.*** With water-control devices, a good supply of water, and a dike, waterfowl can be attracted in the fall or winter to lowland grain fields with heavy soils or to woodlands of oak or other nut-producing trees by flooding them to a depth of one to 12 inches. These "greentree" reservoirs should be drained before tree growth begins in the spring. It should be determined whether state and local laws permit diversion of natural waters for this purpose.

*6-2.5.11. Planting.* It may be possible to increase or optimize wildlife use of wetlands through the introduction of aquatic plants or the control of land use in adjacent uplands. As in the introduction of muskrats, water plants tend to establish naturally in areas suitable for them, even in new impoundments. The planting of perennial aquatic plants, therefore, is usually unnecessary and, often, the survival of the introduced plants is poor. Under the proper conditions, however, perennial plantings can hasten the establishment of vegetation in new waters and improve conditions in older or natural areas. Such plantings should be done with the advice or assistance of biologists familiar with wildlife values and the requirements of the plants. Generally, in stable impoundments, submerged aquatics such as pondweeds or true emergent plants such as bulrushes do best. In areas with fluctuating waters, annual food plants such as millets and woody emergent plants such as buttonbush and willows may be more suitable. Along the shorelines of impoundments and marshes, wild millet, smartweed, sedges, panic grasses, and rice cutgrass may do well. Additional suggestions regarding aquatic plantings can be found in Practical Wildlife Management (app B, No. 15), Waterfowl Tomorrow (app B, No. 62), and Wildfowl Food Plants (app B, No. 68). Some species utilizing wetland areas also use crops or other vegetation in the surrounding uplands for cover or food. Thus, green grain crops such as wheat or perennial pastures or crop residues remaining from the harvest of corn or soybeans provide valuable food for geese. Crop residues, particularly in harvested corn fields, also serve as a food source for ducks. Pheasants, which find marshes suitable for winter cover, may need alfalfa or other crop fields for nesting and grain fields for feeding sites.

*6-2.5.12. Buildings and Roads.* It is desirable to avoid construction of buildings and roads in wetland areas. If unavoidable, the structures, particularly in estuarine areas, should be designed to permit the natural flow of water. Permits are necessary under Section 404 of the Federal Water Pollution Control Act of 1972 as Amended (33 U.S.C. 1344, 86 Stat. 816). Any activities which may affect wetland must comply with Executive Order 11990 "Protection of Wetlands".

*6-2.6. Technical Assistance.* Among Federal agencies, the Fish and Wildlife Service has had much experience in wetland habitat management. Its "Wetland Management Guidelines", although intended for in-house use and under revision, may be used as a reference by installations in the North-Central States. The Bureau of Land Management published "Dabbling Ducks-Tribe Anatini" (BLM Manual Technical Supplement 6601-5, Release 6-27, 3 March 1972) which provides useful information on the management of these ducks. The Forest Service has developed a rather comprehensive Wildlife Habitat Improvement Handbook (app A, No. 9) in which Chapter 30 deals with wetland improvement. The Soil Conservation Service (app C) can provide useful information on water-control structures and other aspects of wetland habitat management. There are also a few wild game food nurseries which can supply seed, roots, tubers, or growing stock for wildlife plantings.

**6-3. Upland Agricultural Habitat.**

*6-3.1. Animals which May Benefit.* Agricultural land provides habitat for many kinds of wildlife, particularly if shelterbelts, small farm woodlots next to cultivated land, old fields which have not reverted to forest, and pasture fields are included. Many game species, small mammals, fur animals, and some songbirds which use such areas are non-migratory or resident species. Migratory birds, as well, frequent agricultural habitats of various kinds. The upland plover which winters in South America may still be seen locally in the spring and summer in pastures or grass fields of the northern United States, and the farm woodlot may be alive with wood warblers during migration periods. Farm game species, particularly the cottontail rabbit and the bobwhite, have small home ranges. Other important farm game species are the ring-necked pheasant, the Hungarian partridge (not now as common in the United States as formerly), and the fox squirrel of which optimum populations are often found in woodlots adjacent to corn fields. The mourning dove, a species which may be seen in large numbers during migration and which nests widely in the country, is included in the discussion of agricultural habitat since waste grain and weed seeds on cultivated land constitute much of its food.

*6-3.2. Objectives.* Management objectives for agricultural land are: meeting the requirements of wildlife for food, water, cover, and breeding space; ensuring survival of the species; maintaining needed habitat; and promoting recreational and other values of the resources. As in the management of other habitats, consideration should be given to other natural resources and activities (primarily farming, agricultural crops, and small woodlots) and if management is directed towards selected or preferred species, to the effects on other species.

*6-3.3. Maintenance of Existing Habitat.* If optimum habitat exists, or if a unique biological community is present, every possible effort should be made to maintain it. In some agricultural areas, for example, there may be remnants of native prairie grasses vital to certain prairie wildlife. As a rule, such remnant communities cannot be maintained over a long period of time without management. Agricultural land is usually fertile and capable of producing large wildlife populations if managed for that purpose. On flood plains where the flooding frequency is such that agriculture cannot be practiced economically or without great risk, more of the land could be devoted to wildlife. Often, flood plains contain woody cover along streams and lend themselves to wildlife management.

*6-3.4. Management and Development.*

*6-3.4.1. Edges and Cover Interspersion.* Due to the small home range of many farm wildlife species, development of good interspersion of food and cover is particularly important. A diversity of cover types adjoining one another as edges or in an interspersed manner enables wildlife to secure food close to the cover it requires for nesting, loafing, or escaping predators. Edges can be created by keeping field sizes small and developing good strips of cover between fields (for example, along fencerows, drainage ditches, or diversion ditches) or between woodlots and fields. Information on the development of edge cover is available from the Soil Conservation Service. The Service can also provide information on shelterbelt plantings which help diversify cover, particularly in the Plains states, and which are important nesting sites for mourning doves and other wildlife.

*6-3.4.2. Cover for Agricultural Wildlife.* Diversification of cover can be increased by planning crop rotations so that adjoining fields contain different crops harvested at different times. Many small woodlots in the East and Midwest are grazed by livestock to the extent that little undergrowth remains. For many types of wildlife, including songbirds, cessation of grazing will, after a few years, result in the growth of ground cover, shrubs, and saplings which constitute three additional layers of cover, each one preferred by certain species or used, in combination, by other species. Where woodlot cover is too dense or uniform, the creation of small openings results in more edges and more diversity of food and cover. Species such as the cottontail frequently use brush piles constructed in such a manner that there are entrances and space left beneath the piles (fig. 6-4). Also, brush piles can provide escape cover in open spaces between tracts of living, woody cover, thus forming a sort of travel lane. Vegetation management, whether through outlease agriculture, woodlot management, or practices more specifically aimed to enhance wildlife, is a principal approach to wildlife management on agricultural land. Agricultural crops, or portions thereof, in fields adjacent to wildlife cover may be left unharvested as food for wildlife or as nesting cover in the case of alfalfa or sweet clovers which are particularly valuable for nesting pheasants. Sweet clover, if left standing until fully mature and then harvested with a combine for seed, provides excellent nesting cover for pheasants. The harvest can be late enough that nesting is not disrupted with loss of birds and eggs, as occurs in regular haycutting operations. Controlled or prescribed burning may be needed to maintain stands of native prairie grasses. Disking stands of bunch grass in old fields can stimulate the growth of herbaceous plants more valuable as wildlife food. Cutting is another method of controlling vegetation. Freeing or releasing old apple trees at the site of previous farm residences so that there is less competition with other trees can increase the production of fruit attractive to many kinds of wildlife. Selective herbicide treatments can be used to help establish shrubs and maintain vegetation in the successional stage most desirable for certain types of wildlife. Plantings, whether annuals in wildlife food plots or shrubs and trees in border plantings, can help diversify habitat. Such plantings also control erosion and add beauty to the area. The importance of travel lanes or corridors connecting one area of cover with another and providing access to feeding areas should be kept in mind. Finally, in the interest of diversity, wetland areas within agricultural areas should be maintained whenever possible. Development of water catchments, small ponds, and other water areas can be very beneficial to doves, muskrats, fish, reptiles, amphibians, and other wildlife.

*Figure 6-4. A brush pile for wildlife.*

***6-3.5. Technical Assistance.*** Technical assistance can be obtained by contacting the Federal agencies listed in subparagraph 6-2.6. Many good suggestions on managing agricultural habitat appear in Practical Wildlife Management (app B, No. 15).

### *6-4.* Forest and Range Habitat.

***6-4.1. Animals Which May Benefit.*** Forest and range habitat, literally and figuratively, covers a great deal of territory and involves many species of fish and wildlife, from the endangered spotted bat to the bighorn sheep or moose to the burrowing owl to the golden eagle or California condor. Included are hundreds of species of nongame birds (songbirds, predators, etc.) and many species of game birds (grouse or various types, wild turkey, woodcock, Chukar partridge, and various species of quail and dove). In addition to a host of bats, small mammals (mice, shrews, moles, ground squirrels, and other rodents), predators (coyotes and foxes), and fur animals (beavers, pine martens, skunks, opossums, and raccoons), many game mammals are found in forest and range habitat. Among the latter are tree squirrels, deer, other ungulates, and bears.

***6-4.2. Objectives.*** Management objectives include: optimizing the abundance and diversity of fish and wildlife in an area; maintaining areas of high wildlife productivity which already exist on an installation; improving for fish and wildlife other areas on an installation consistent with other natural resource management objectives and needs; optimizing the kinds, amount, and quality of wildlife and wildlands-oriented recreation; and helping to assure survival of an area's plant and animal species including, particularly, threatened and endangered species. As an example of the latter, living, mature pine trees with heart rot are being retained for the benefit of the red-cockaded woodpecker at Eglin Air Force Base, Florida, Fort Benning, Georgia, and other installations in the South.

*6-4.3. Rehabilitation and Development.* Rehabilitation and development practices for forest and range habitat are similar to those recommended for other habitats. Although major attention is given to vegetation management, provision of water may be quite important. Also, the relationship of livestock grazing to wildlife may be of concern. The same principles of cover diversity, cover interspersion, and edges apply to forest and rangeland areas as elsewhere.

*6-4.3.1. Provision of Water.* Where water is limited, as in much of the Southwest, the carrying capacity of some forms of wildlife can be increased by developing or providing additional water. Various types of watering devices, frequently called "guzzlers", are used in the Southwest for quail, deer, bighorn sheep, and other wildlife. Instructions for making these guzzlers and criteria for spacing them appear in the Wildlife Habitat Improvement Handbook (app A, No. 9). Spacing depends upon food and cover conditions and the daily cruising radius of the species. Thus, the California Valley quail may range from one-half to one mile, the Mountain quail may range two miles, and the Gambel quail, three to five miles. For deer, development of waters is suggested at one-mile intervals at sites with suitable food and cover. Guzzlers basically consist of a hard-surface apron to collect maximum rain and runoff and to carry water to a storage tank. In addition, waterholes can be constructed, windmills installed and springs developed in some areas. Often, fences are necessary around such developments to keep out livestock. Adequate cover should be provided around a watering area. The Forest Service, Bureau of Land Management, Fish and Wildlife Service, and state conservation departments can advise on watering facilities.

*6-4.3.2. Control of Grazing.* Overgrazing and overutilization by livestock can result in serious degradation of forest and rangeland and can lead to accelerated erosion and siltation of streams and lakes. Grazing tends to remove much of the ground cover and shrub layer and thus reduce the diversity of vegetation. When overgrazed areas are protected from grazing, or when grazing is reduced, vegetation comes back, and so does a greater variety of wildlife. Regulated grazing can help keep vegetation at the stages preferred by some wildlife species; for example, species which utilize seeds of annual weeds as food.

*6-4.3.3. Forest Management.* The methods, extent, and frequency or timing of timber harvests are of prime importance in determining food and cover conditions for wildlife. Solid stands of timber of fairly uniform size or large plantations of a single species often are not particularly productive of or attractive to wildlife. In stands with a dense canopy, most photosynthesis occurs high above ground level, and the stored energy is concentrated where deer and other ground-dwelling animals are unable to use it. Opening the canopy permits more sunlight to reach the ground and results in the growth of more plants for food and cover. Following are recommendations for the creation of openings:

*6-4.3.3.1.* Forest openings may occur naturally as a result of fire, storm, insects, disease, or site conditions. Other openings are caused by man in building roads, firebreaks, and utility line rights-of-way or as a result of fires. In many forest areas, there are abandoned farm homesites or old orchards. All openings in otherwise closed canopy forests are valuable to wildlife. If well-scattered openings do not make up about five percent of the forest area, such openings should be created if increased wildlife is an objective. Clear-cutting in blocks or strips creates openings and increases the edge effect. For maximum diversity, there should be various successional stages and mixtures of tree species close to forest openings or borders. The clovers, lespedeza, and other legumes often found in forest clearings are used as a source of green vegetable matter by grouse and turkeys. Insects found on the vegetation in clearings supply a source of high-protein food for young birds. Clearings also provide forage for elk, deer, rabbit, woodchuck, and other species.

*6-4.3.3.2.* With respect to the number and size of openings recommended, the Forest Service suggests one-half to one-acre openings at one-quarter-mile intervals for quail and grouse and larger openings, two to five acres at one-half-mile intervals, for wider-ranging birds such as turkey and for deer. More openings are needed in large stands of small pole timber than in sparse sawtimber stands. Wildlife travel lane areas adjacent to streams, ponds and lakes and on ridges or in valleys, are desirable site locations for openings.

*6-4.3.3.3.* In addition to timber harvesting, openings can be created by bulldozers or herbicides. They can be maintained with prescribed burns, cultivation, cutting, herbicides, or the use of heavy disks, rotary choppers, mowers, heavy chain drags, and rollers. Clones of some shrubs, once well-established, resist tree invasion for many years, and perennial grass stands can hold brush reinvasion to a minimum. There should be close coordination and cooperation between the wildlife manager and the forester. In constructing logging roads and harvesting timber, erosion should be minimized to avoid unnecessary turbidity and siltation in streams. Logging debris should be kept out of streams and lakes. Leaving buffer strips of uncut timber and shrubby vegetation along streams is also recommended.

*6-4.3.4. Cover-Type Conversion on Rangeland.* Attempts to convert extensive areas on one major vegetation type to another, such as sagebrush to grasses, can be detrimental to species like the sage grouse if proper care is not taken. The Wildlife Habitat Improvement Handbook (app A, No. 9) contains specific guidelines to providing for the sage grouse by leaving corridors, islands, and blocks of sagebrush intact. It is indicated, for example, that a sagebrush-control project should affect no more than 50 percent of the sagebrush stand concerned. Similarly, guidelines have been developed for avoiding damage to deer and elk habitat in juniper-pinyon clearing projects in the Southwest. These guidelines involve the principles of diversity and interspersion of cover types in various stages of plant succession.

*6-4.3.5. Prescribed Burning.* Prescribed burning can be a valuable tool for improving habitat. It is used widely in the South in quail management. The Michigan Department of Natural Resources and the Forest Service employ controlled burning as a vital part of a cooperative program in Michigan to conserve the Kirtland warbler.

*6-4.3.6. Other Approaches.* Other approaches to wildlife management include: special wildlife plantings; construction of brush piles; top-pruning of trees to provide slash and promote bushy tree growth for roosting cover; preservation of den trees or trees with natural cavities used by various squirrels, wood ducks, some woodpeckers, and other species; preservation of nesting trees used by such species as the bald eagle and osprey; retention of known roost trees of turkeys and rookeries for other important species; retention of standing dead trees for woodpeckers, flying squirrels, and other hole nesters and as perches for raptors; and use of salt or other nutrient supplements for deer.

*6-4.4. Technical Assistance.* Assistance on wildlife management in forest and rangeland habitats can be obtained from the Forest Service and the Bureau of Land Management (app C). The Bureau has published a series of Technical Notes, titled "Habitat Management Series for Unique or Endangered Species", which provides a description of the species; summarizes information on its status and population trend, distribution, life history, habitat requirements, and limiting factors; lists protective measures instituted; provides species and habitat management recommendations; lists authorities on the species; and cites references. Useful information on prescribed burning, fire ecology, and ecological control by habitat management is available from the Tall Timbers Research Station (app c, 12). This information applies not only to the South but also to other parts of the country.

**6-5. Stream Habitat.**

*6-5.1. Scope.* Streams and rivers transect other habitat types and are affected by the land use within their respective watershed. Varying in size from mere trickles at the head to large, tide-influenced rivers at the outlet to the sea, they provide habitat for myriads of aquatic organisms, both plant and animal, and for other species which use flowing waters as part of their environment. Streams and rivers are used by many birds and mammals in addition to fish, ranging from small darters to sturgeons, and by amphibians, reptiles, and a host of invertebrates and microscopic forms of plants and animals. Thus, the water ouzel may be seen diving into swift Rocky Mountain streams, and pelicans and gulls may be seen using tidal river areas. Beaver may occupy mountain streams and build dams while the large, plant-eating manatee may be found in some Florida rivers and canals. Some species of fish, like salmon, come from the ocean and swim up streams for spawning; they are designated as anadromous. Other species, like the eel, which swim from freshwater streams to the ocean for breeding are called catadromous. Dams and other structures, such as culverts, built by man may obstruct the movement from sea to inland stream. Also, timber harvesting, agriculture, industrialization, and urbanization may affect the quality or quantity of water needed in streams or rivers for certain animals. Consumptive use of water from streams may result in a minimum flow too little to support certain species. Dams, which back up water, may so change habitat conditions that some species are extirpated or endangered. Use of water for irrigation may result in water so degraded in the return flow, due to increased salt content or chemical fertilizers and pesticides, that it will not satisfy the requirements of certain species. Many aquatic species suffer also as a result of stream channelization.

*6-5.2. Objectives.* Management in stream or riverine habitat is designed to ensure survival of the animal species involved and to enhance their recreational and other values. In some instances, this may mean keeping conditions as they are; in others, it may mean practicing rehabilitation or development measures equated with other land use practices and natural resource values. State and Federal agencies concerned with water management should be consulted in advance of improvement projects in order to coordinate work with other programs and needs. It is expected that emphasis in management will be on endangered and threatened fish species and on various featured species, depending upon the aquatic environment and its potential. The upper reaches of streams are smaller and likely to have clearer, cooler, less fertile waters than downstream. In the eastern United States, they may contain brook trout, the transplanted rainbow or brown trout, or smallmouth bass. Downstream, the smallmouth bass and other species less tolerant of siltation and changes occurring as a result of agriculture and other land uses may give way to catfish, carp, and suckers. In larger rivers, most of the common game and panfish characteristic of the area are likely to be found either in the main channel or in backwaters, sloughs, oxbows, bayous, and overflow ponds. These species include largemouth bass, crappies, other sunfish, and bullheads. In the tidal or estuarine reaches of rivers, special consideration should be given to flounder and striped bass. In addition to fish, management of stream and river habitat, involves consideration of plankton, invertebrates such as crustaceans, birds, and mammals, all of which are affected by land use in the watershed any by any other activities which may alter the stream habitat.

*6-5.3. Relation of Stream Conditions to Watershed.* Plan the land use of the watershed to minimize soil erosion, sedimentation, pollution, channelization and regulation of stream flow.

*6-5.3.1. Soil Erosion.* Products of soil erosion can fill pools, cover food-rich areas with barren materials, increase turbidity, destroy cover, cover spawning areas, and cause serious mortalities (for example, among salmonid embroyos, alevins, and fry still in the gravel). Mention has been made of the need to control erosion in construction of roads in forested areas. Care needs to be exercised, elsewhere, in road and other construction activities; and in connection with agriculture and range management, with respect to grazing intensities to avoid accelerated erosion. Settling ponds, used in connection with gravel washing and mining operations, can help reduce siltation in streams.

*6-5.3.2. Pollution.* Care in the use of pesticides on agricultural land, forest, rangeland or developed areas can reduce stream pollution. Abandoned mine tunnels, a source of acid waste, sometimes can be plugged. State water quality standards required by the Water Quality Act of 1965 should be reviewed. When stream pollutants exceed the tolerances defined by these standards, an effort should be made to take corrective abatement action.

*6-5.3.3. Channelization.* Stream channelization should be kept to a minimum. Additional bridges or the careful routing of roads sometimes can lessen the amount of channelization. Following channelization, rehabilitation measures can help restore a channel to conditions approaching the original if the length of the stream has not been too greatly reduced. Maintaining buffer strips of native vegetation along streams or planting and managing riparian vegetation provides insect food and cover, reduces erosion, and controls water temperature. If stream banks are well stabilized by vegetation, there can be some undercutting of the banks by erosion which will provide shade and hiding places for fish or mink without sloughing off the upper part of the bank. Various species of willow are often used for streambank planting. Planting fresh cuttings in permanently moist soil, while the willows are dormant, has proven successful, provided populations of hungry muskrat, beaver, or deer are not too high. If they are a problem, other native trees or shrubs might be tried. Fencing, with water gaps for livestock, can be used to protect riparian vegetation from livestock.

*6-5.4. Regulation of Stream Flow.* Regulation of stream flow can best be attained by headwater improvements on streams, creating controlled storage and releases, or by adequate releases from existing structures. This requires coordination with other interests. Advice on the timing and amounts of release should be sought from biologists knowledgeable about the requirements of stream biota.

*6-5.5. Stream Improvement Practices.*

*6-5.5.1. Improving Channelized Areas.* Channelized portions of a river can be developed with the installation of instream rehabilitation structures, such as deflectors and check dams, so that the hydrological features resemble unchannelized streams. This is described in "Rehabilitation of a Channelized River in Utah" (app B, No. 5). Conditions for fish and the aquatic organisms on which they depend can be improved in channelized streams by such measures. In some cases, these measures can improve unchannelized, but otherwise degraded streams, as well. The Wildlife Habitat Improvement Handbook (app A, No. 9) provides details on the construction and use of various types of dams, deflectors, and other devices or approaches for direct channel improvement. The Forest Service recommends, for stream improvement, that dams be restricted to streams whose maximum flood volumes do not exceed 100 cubic feet per second; the Service suggests that deflectors may be installed in larger streams.

*6-5.5.2. Creating Cover and Resting Places.* The creation of pools for resting places and shelter for fish is one of the principal objectives of stream improvement. The deeper pools found in intermittent streams also have value for muskrats if located in food-rich places (for example, near a corn field). Large boulders, two-thirds of a cubic yard or larger, placed in broad, shallow, fast-velocity channels with gravel or rubble bottoms can produce resting places for fish. Brush and trees carefully secured by cables to stumps or trees along the banks of small streams can be used to provide cover for fish. They should not be used in situations that would block fish passage or cover known gravel spawning beds.

*6-5.5.3. Improving Spawning Conditions.* Although most egg-laying fish deposit their eggs above the bottom, species such as salmon and trout bury their eggs below the bottom on gravels of different sizes. When the spaces between the gravels are filled in with sand or silt, conditions are unsuitable for spawning and survival of the eggs and young fish. When the gravels have become cemented by fine sands and silt, they may be loosened mechanically by raking, harrowing, disking, plowing, spading, or dozing. Such work should be done when eggs and larvae are not in the gravels, and the effect on downstream conditions should be evaluated. Another method used by the Forest Service is gravel cleaning. In this operation, a mobile machine drags harrow-like teeth through stream gravels to a depth of 14 inches; high-pressure jets of water are released into the gravel through the teeth; a vacuum-cleaner device above the disturbed gravel sucks up the finer materials; and the slurry of fines is pumped through a high-pressure nozzle 100 feet back of the stream bank.

*6-5.5.4. Creating New Spawning Beds.* New spawning beds can be created by trapping gravels in a stream with low dams or right-angle deflectors or by introducing graded gravels in excavations designed to hold them. Larger species of salmon may use spawning gravels up to six inches in diameter while trout and fish of similar size use gravel up to two inches in diameter. Special artificial spawning and hatching channels can be constructed in cooperation with state or other agencies under cooperative agreements or special use permits. Details on these approaches are contained in the Wildlife Habitat Improvement Handbook (app A, No. 9).

*6-5.5.5. Facilitating Fish Passage.* With anadromous species (which move up river from the sea to spawn), in particular, consideration should be given to facilitating fish passage. Although complex fish ladders and other approaches are needed for high dams, blockage of fish passage on installations is more likely to be caused by culverts or low dams which require less sophisticated approaches. The Wildlife Habitat Improvement Handbook treats this problem in considerable detail. Fish Migration and Fish Passage—A Practical Guide to Solving Fish Passage Problems (app B, No. 34) contains a series of graphs to aid biologists and engineers in determining velocity and water depth (of critical importance in fish passage) for the most common types of culverts.

*6-5.5.6. Improving Conditions for Warm-water Fish.* Many warm-water fish need resting and holding areas protected from fast currents. Spawning areas for sunfish, black bass, channel catfish, and other warm-water fish should be protected from strong currents. Lagoons, side channels, and large eddies that contain logs, brush, and deep holes for cover and feeding sites should be protected, improved, or constructed. Ponds or oxbow areas connected to the main stream channel during floods can be very productive for small fish. Abandoned dredge ponds and gravel pits adjacent to streams can also be good fish-rearing locations, especially if temperature and water conditions can be improved by diverting some stream flow through them.

*6-5.5.7. Adding Nutrients.* There may be situations in headwaters where nutrients are low, or in other stream stretches where water chemistry conditions are extreme. In these situations, adding chemicals or nutrients will help support fish. Food supplies in upstream waters may be augmented temporarily by placing porous sacks of agricultural fertilizer (e.g., a 4-12-16 analysis) in the waters.

*6-5.5.8 Considering Birds and Mammals.* Other wildlife can benefit from the management suggested for fish. If beaver is selected as a featured species in stream management, preferred foods, such as willow, aspen, and serviceberry, should be retained adjacent to the stream. Dams built by beaver may benefit muskrat, raccoon, mink, woodcock, and waterfowl such as woodducks, but they may also reduce much needed winter cover for deer in protected valleys. Beaver ponds may increase water acreage for trout for a couple of years; but thereafter, when the stream bank cover has been consumed, resulting in rising water temperatures, and when populations of competing species of fish such as the creek chub and dace develop, the effects on trout may be detrimental. On the other hand, beaver ponds may increase the carrying capacity of streams for warm-water fish. Beaver dams and the beavers' tendency to plug culverts may lead to the flooding of roads. The pros and cons are controversial, but if kept under control, the beaver can be a valuable asset. Waterfowl use rivers as resting areas during migration in the fall, and some species nest in riparian vegetation. River hunting for waterfowl is important from a recreation standpoint. On the other hand, portions of some rivers can serve as sanctuaries if areas having concentrations of waterfowl are posted against hunting.

**6-6. Lake and Impoundment Habitat.**

*6-6.1. Definitions.* There is no rule that states how large or how deep a body of water must be to be called a lake, nor is there a clearly defined distinction between a lake and a pond. The origin of natural lakes is associated with glacial action, volcanic action, warping of the earth's crust, and other natural phenomena. Ponds, usually regarded as bodies of water too small to be called lakes, may have a natural origin or be man-made. A water body large enough to be considered a lake in one part of the country may be considered a pond or pothole in another. Reservoirs, also varying greatly in size, are man-made impoundments or controlled lakes in which water is collected or stored. There are important distinctions between artificial reservoirs and natural lakes. Reservoirs are so constructed that they contain very little dead storage (i.e., most of the water is above the level of the lowest outlet and can be released if necessary); on the other hand, almost all water in natural lakes is below the level of the natural outlet. Another difference is that, as compared with their total contents, reservoirs generally have larger inflow than lakes. Principal Lakes of the United States (app B, No. 14) further discusses these distinctions. From the standpoint of fish and wildlife, a lake, reservoir, or pond with water-level control facilities provides more flexibility for management. However, if fish and wildlife values are not given adequate consideration, a reservoir may not be as productive biologically as it could be.

*6-6.2. Animals which May Benefit.* Ponds, lakes, artificial impoundments, and the land adjacent to them provide habitat for a great variety of warm-water and cold-water fish and the organisms on which they feed. They provide suitable habitat for numerous other wildlife species, including amphibians, reptiles, birds, and mammals.

*6-6.3. Objectives.* Management objectives include preservation of threatened and endangered species and their habitat, enhancement of fish and wildlife in general, management for preferred species, and conservation for the public benefit, including outdoor recreation and aesthetic and scientific values.

*6-6.4. Scope.* Considered herein are large, multipurpose impoundments built on rivers and smaller impoundments, ranging from 20 acres to one acre or less, constructed for fishing and recreation. Lakes, ponds, and reservoirs are all bodies of water surrounded by land and affected by its uses and activities. Each has a biological community dependent, in part, on the physical and chemical characteristics of the area. Around the shores of many impoundments, particularly at the upper end or where tributary streams enter reservoirs, there are usually wetland or marshy areas. Management of these areas should be much the same as discussed in paragraph 6-2. Larger lakes and reservoirs may have extensive sandy or gravelly shorelines and, during drought periods or drawdowns, mud flats frequented by shorebirds. During the fall and until frozen over in winter, many of the larger reservoirs also serve as resting places or sanctuaries for large numbers of geese and ducks. Reservoirs affect the distribution and migration patterns of waterfowl which use them as resting sites and surrounding grain fields as feeding grounds.

*6-6.4.1. Sedimentation and Eutrophication.* In a geological sense, natural lakes are relatively short-lived, and reservoirs are likely to fill quickly with sediment as a result of accelerated erosion and siltation. Small, shallow ponds, whether natural or man-made, also shrink in size from invasion of vegetation and may become eutrophic or over-enriched with nutrients, resulting in the rapid growth of algae. With decomposition of these plants, dissolved oxygen may be used up, resulting, in turn, in fish kills. In shallow, northern ponds and lakes, snow covered ice may also cause winter kills due to lack of sufficient oxygen.

*6-6.4.2. Pollution.* Although subjected generally to the same types of pollutants as rivers, the problem in lakes is compounded because of the relatively slow replacement of water. Whereas pollutants in rivers tend to be carried downstream and diluted, those in lakes are more confined over longer periods of time. Large reservoirs, if completely drained, may require two years or so to refill, but in Principal Lakes of the United States (app B, No. 14), it is suggested that Senaca Lake in New York might require 10 years and Lake Tahoe, as much as 300 years, to refill.

*6-6.4.3. Thermal Stratification.* Another important characteristic of larger and deeper lakes and reservoirs is the mixing and thermal stratification of water. In most natural lakes and reservoirs, wind and wave circulation maintains fairly uniform temperatures from top to bottom. With the approach of summer, wind velocities decrease, and the sun warms the surface water, causing it to become less dense than the colder water below. The warm surface waters may mix to a depth of 15 to 40 feet. Below the warmer waters is a transition zone called the thermocline, which may vary from five to 50 feet (usually, the water temperature drops about 0.6°F. per foot), and below the thermocline, the water temperature is cold (ranging in big, fertile reservoirs from 46° to 60°F.). In the fall, the surface water cools and becomes denser and heavier than the lower water. Coupled with wind action, this results in the so-called fall turnover. During the fall and spring periods of mixing, the oxygen which has been added to the upper level by wave action and photosynthesis is distributed throughout the lake. Thermal stratification is further described in "Big Reservoirs" (app B, No. 50).

*6-6.5. Management Implications of Thermoclines.* The fact that many larger reservoirs have thermoclines with cold water beneath and warm water above enables biologists to manage for the combined production of warm-water fish and trout. Also, in the case of hydropower dams with outlets at the bottom, the release of cold water permits trout fisheries to be established downstream.

*6-6.6. Fish Production Potentials.* A study by the Fish and Wildlife Service's National Reservoir Research Program, described in "Big Reservoirs" (app B, No. 50), revealed that the impoundment producing the highest angler catches hypothetically would be two to six years old and would have a dissolved solids content of 200 parts per million, an average depth of 20 feet, a relatively long and irregular shoreline, a low water exchange rate, and a long growing season. Fish and Wildlife Service studies also indicate that the average reservoir supports approximately 80 pounds of sport-type fish per acre. At least 50 percent of that crop can be harvested by anglers each year without jeopardizing future production. This means that the current average yield of 17 pounds per acre could be doubled without endangering the population. Among the species produced in reservoirs and lakes are largemouth bass, crappie, rainbow trout, white bass, northern pike, walleye, yellow perch, carp, and suckers. Threadfin and gizzard shad serve as forage fish in many impoundments.

*6-6.7. Reservoir Management.* Drawdowns which expose parts of the reservoir bottom in the fall or winter tend to increase nutrients for plankton when the bottom is reinundated in the spring. Also, when fish are concentrated by extreme drawdown, unbalanced populations can be eliminated more economically with selective chemicals. Increased fishing can be promoted by providing fishing piers and docks. The construction and annual maintenance or refurbishing of submerged brush shelters concentrate crappie and other species for the angler, as does the winter discharge of warm water from steam power plants.

*6-6.8. Cold-water Ponds.* Cold-water ponds where water seldom gets above 70°F. in summer are best suited for trout. Trout do not spawn in these ponds; therefore, the ponds should be restocked at least every two or three years. Rainbow trout are the most commonly available species for stocking. Brown trout will grow in slightly warmer water than that required for rainbow, brook, or cutthroat. Food supplies naturally available in ponds usually are sufficient to grow and support 50 pounds of trout or more per acre; however, a pond's carrying capacity can be increased by using manufactured fish foods in pellet form. Stocking cold-water ponds is further discussed in "Farm Ponds" (app B, No. 26).

*6-6.9. Warm-water Ponds.* In warm-water ponds, water temperatures rise to 60° or 70°F. early in the spring and remain above 70°F. throughout the summer. The most successful combination of fish for stocking warm-water ponds is bluegills and largemouth bass. Channel catfish stocked in warm-water ponds and fed commercial pelleted fish feeds may produce up to 1,000 pounds or more per surface-acre, but they do not reproduce successfully in small ponds. Channel catfish grow best in water with temperatures between 70° and 90°F. Black, brown, and yellow bullhead catfish prosper in warm-water ponds, but they spawn repeatedly and usually overpopulate the water seriously. Stocking warm-water ponds is further discussed in "Farm Ponds" (app B, No. 26). Information on maintaining a good balance between largemouth bass and bluegills or other forage fish and on managing small impoundments to permit optimum harvests is available in "Symposium on Overharvest and Management of Largemouth Bass in Small Impoundments" (app B, No. 37). Fish pond management is not a simple operation, and guidance from experts in state conservation departments, universities, or Federal agencies such as the Fish and Wildlife Service (app C, No. 6c) and the Soil Conservation Service (app C, No. 4c) should be sought. They can provide helpful information on pond construction, stocking, fertilization, weed control, and elimination of undesirable fish.

*6-6.10. Pond and Lake Improvement.*

*6-6.10.1. Coordination and Legal Aspects.* When planning improvement projects, many factors must be considered, including: determination of water rights and prior uses that would conflict with the project purpose; coordination with other resources and land uses; coordination with the state fish and game agency to avoid conflicts with state management plans; evaluation of physical and biological features; checking the quality of the water with Federal and/or state water quality standards for possible detrimental effects of the impoundment upon downstream water, especially its temperature; and careful planning, design, construction, operation, and maintenance of the project.

*6-6.10.2. Improvement of Habitat.* Many existing ponds or small lakes could be improved by enlarging and deepening. In the case of natural lakes, this could possibly be accomplished through construction of a dam across the outlet, which may result in increased productivity and eliminate winterkill. Addition of brushy cover in the water may provide needed shelter. From the standpoint of birds and mammals, borders of shrubs and herbaceous marsh plants, such as cattails, burreeds, arrowheads, wild millet, wild rice, bulrushes, smartweeds, and reed canary grass, around a pond or lake may be beneficial. Dense growths of such cover, however, may render bank-fishing very difficult and may promote the survival of too many young fish.

*6-6.10.3. Water Level Control.* It is recommended that facilities for controlling water levels be included in new water development projects. For example, the ability to drop the water level in an impoundment overpopulated with stunted panfish will force many of these forage fish out of the weed beds and into areas where predator fish can get them. Drawdowns are reported to have been used to control carp by leaving carp eggs stranded on an exposed shoreline shortly after spawning and to control bullheads and mudminnows in northern impoundments through winterkill. On the other hand, by raising the water level, additional marshy areas which may improve conditions for northern pike spawning and for waterfowl can be created. In most cases, water control systems should be designed for bottom draw of water to provide better oxygen distribution.

*6-6.10.4. Improvement of Conditions for Spawning.* Other means of improving conditions for spawning in lakes include the introduction of gravel or crushed stone and the installation of various artificial spawning structures. The natural reproduction of some large catfish, especially channel catfish, can be encouraged by installing drain or flue tiles in new reservoirs before filling the impoundment. The tiles, with one end filled with concrete, should be laid almost horizontally in a small trench on the lake bottom three to five feet below the conservation pool level where they can serve as holes in which catfish spawn. This structure is further described in the Wildlife Habitat Improvement Handbook (app A, No. 9).

*6-6.10.5. Improvement of Cover.* In clear-water lakes, provision of cover attracts fish. Brush can serve as egg-attachment sites for some minnows and insects as well as escape cover for forage fish. In new impoundments, some brush or standing timber can be left in place; in existing, northern impoundments, brush and log shelters can be constructed, weighted, and placed on the ice to sink when it melts. These structures should be placed in areas of 10 to 15-foot depths but above the zone of summer and winter stagnation. Construction of islands and floating nest boxes is also useful for waterfowl and other wildlife.

*6-6.10.6. Vegetation Management.* Plants are an essential part of the natural aquatic habitat. They increase the oxygen content of the water during photosynthesis and serve in various ways for food and cover. The microscopic phytoplankton and so-called algae bloom aid in maintaining clear and fertile water with their metabolic and decomposition products. However, aquatic plants can become detrimental to fish, and dense stands of vegetation can make fishing and other water-based recreation next to impossible. The subject of aquatic plant control is complex but among the approaches are:

*6-6.10.6.1.* Pulling or cutting plants by hand on very small areas or by specially designed machines on larger areas.

*6-6.10.6.2.* Reducing photosynthesis through dyes or plastic sheeting which cut down the light penetrating the water.

*6-6.10.6.3.* Biologically controlling the plants. There have been experiments with the manatee, some herbivorous fish, and certain plant diseases.

*6-6.10.6.4.* Chemically controlling plants which, while probably the most effective, practical method, has limitations. Any state or Federal regulations on the use of algacides or other chemical weed killers must be adhered to, the applicator must be qualified or licensed, and the work must be coordinated with other concerned agencies. The right chemical should be used at the right time in the life cycle or growth stage of the plant and in accordance with the label on the chemical container.

*6-6.10.6.5.* Fertilizing certain types of submersed aquatic plants, particularly in the Southeast. Fertilization increases the organic turbidity of the surface water by increasing plankton composed of tiny plant and animal organisms. These suspended organisms reflect the sunlight from the water surface and impede light penetration necessary for plants in deeper waters. The use of organic fertilizers in the waters of northern states, however, tends to increase the growth of objectional forms of algae rather than plankton algae, thus compounding the problem.

*6-6.10.7. Increase of Biological Productivity.* Since plankton are at the bottom of the food chain, their increase by fertilization theoretically should result in more fish. Many impounded waters are sufficiently fertile so that further chemical enrichment is neither needed nor desirable. Preferably, fertilization should be undertaken only after a complete water chemistry analysis has been made. The advice of biologists should be sought on the need for fertilization and on the kinds, amounts, timing, and manner. Application of inorganic fertilizers may also cause clay particles to settle, thereby reducing turbidity in muddy ponds. Clay turbidity, has been treated in some detail in "Physiochemical Nature of Clay Turbidity with Special Reference to Clarification and Productivity of Impounded Waters" (app B, No. 48).

**6-7. Technical Assistance.** Many helpful publications can be identified by examining, Sport Fishery Abstracts and Wildlife Review, published by the Fish and Wildlife Service. In addition, the Conservation Directory, published by the National Wildlife Federation (app C, No. 8), contains the annually updated names and addresses of most national and international natural resources conservation agencies and organizations, as well as many professional and scientific societies. The Wildlife Management Institute (app C, No. 13) publishes the transactions of the annual North American Wildlife and Natural Resources Conference; and Stackpole Books (app C, No. 11) publishes a series of authoritative books on the life history and management of many of the nation's large mammalian predators, big game, upland game birds, and waterfowl.